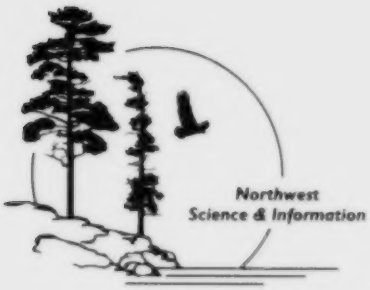

Fall Walleye Index Netting (FWIN) of Sabaskong Bay, Lake of the Woods, Ontario: 2000 and 2005

NWSI Technical Report TR-141

December 2007

Ontario

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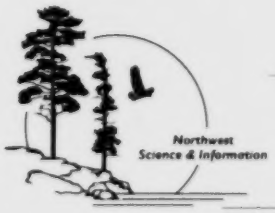
by

T. Mosindy



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Abstract

Results of a 2005 fall walleye index netting (FWIN) project in Sabaskong Bay (Sector 4), Lake of the Woods, Ontario indicated an overall decline in walleye population status when compared with a previous FWIN survey of this sector in 2000. Walleye catch had fallen from 8.9 fish·lift $^{-1}$ in 2000 to 6.5 in 2005. Decreases in the proportion of "quality-sized" fish, in the percentage of fish older than 4 years of age, in the spawning stock biomass, and in the number of contributing age groups in FWIN samples were also observed. Although growth, condition factors and maturity rates were average for northwestern Ontario populations, total annual mortality rates were high and approached 50% for fish of both sexes, age 3 and older. Estimated fecundity had increased from 56.5 to 76.6 eggs·g $^{-1}$. Although abundance remained relatively stable, declines in size and age class structure were observed for most other species. These changes are indicative of increased exploitation, despite reductions in daily catch/possession limits and the introduction of more restrictive size limits for angling since 1999.

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Disclaimer

The views, conclusions, and recommendations are those of the author and should not be construed as either policy or endorsement by the Ontario Ministry of Natural Resources.

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Introduction

This report is based on the results of fall walleye index netting surveys (FWIN; Morgan 2002) conducted by the Lake of Woods Fisheries Assessment Unit, Ontario Ministry of Natural Resources, in Sabaskong Bay (Sector 4), Lake of the Woods during 2000 and 2005. This work supplements a long-term fish community index netting (FCIN) program that has been run in this sector at regular intervals since 1980 (Foote *et al.* 1981, Ontario Ministry of Natural Resources 2004). Most recent FCIN sampling occurred in 2005 and 2006. FWIN data from this study were also compared with results from FWIN projects conducted on other parts of Lake of the Woods in recent years.

Study Area

Lake of the Woods is a 385,000 ha lake, extending 106 km north–south and 105 km east–west. It borders Ontario, Minnesota, and Manitoba with about 65% of its surface area within Ontario (Schupp and Macins 1977). The Ontario portion of Lake of the Woods has been divided into seven sectors for fisheries assessment and management purposes, based on distinct physical and ecological characteristics.

Sabaskong Bay is the smallest sector, covering 18,240 ha and extending east of a line drawn from the mouth of Obabikon Bay, to Rabbit Point, Little Raspberry Island and the mainland between Greens Island and Hanson Bay (Figure 1). This sector is shallower and less clear than the northern sectors.

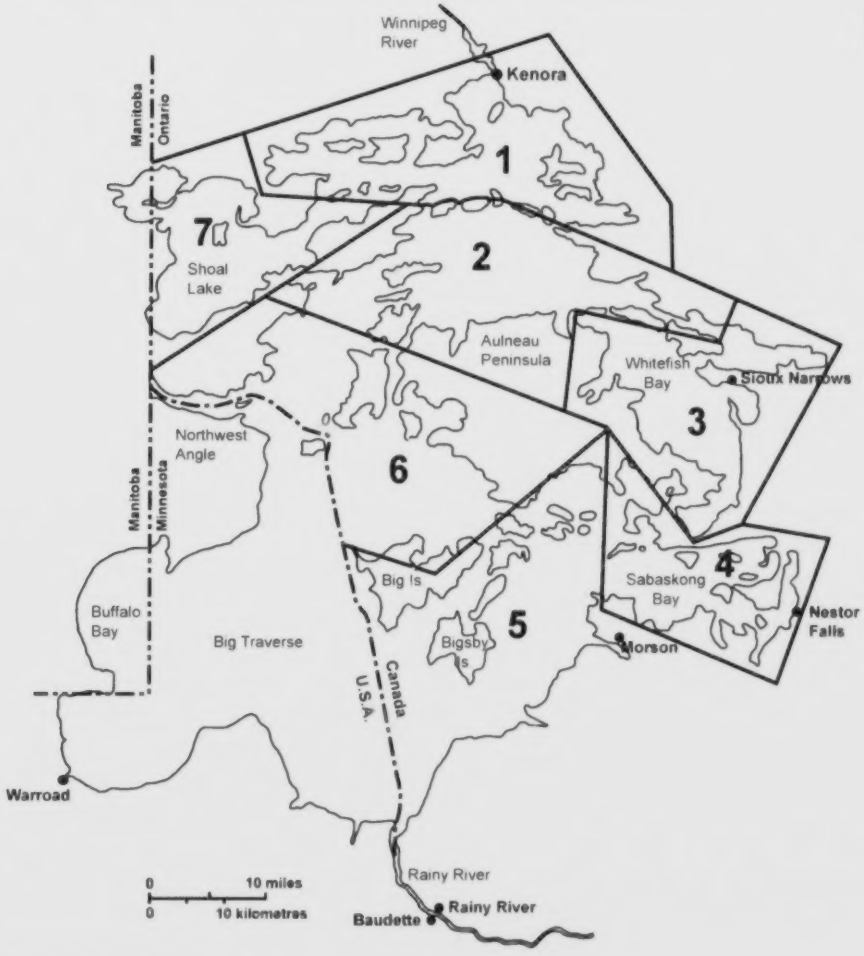


Figure 1. Location of Ontario sectors on Lake of the Woods.

Waters are largely homothermous and well oxygenated during most of the year, although deeper areas tend to become anoxic in late summer and winter. Water clarity is limited to secchi disc values of 1.5 to 2.5 m. However, dense algal blooms composed mainly of the blue-green algae, *Aphanizomenon flosaquae*, can reduce secchi disc readings to less than 1 m in late summer. Sabaskong Bay has an estimated potential fish yield of 4.92 kg·ha $^{-1}$·yr $^{-1}$ (morphoedaphic index; MEI =13.3; Ryder 1965), based on mean depth (4.9 m) and total dissolved solids (65 mg·L $^{-1}$).

Methods

Gill netting in 2000 and 2005 followed the FWIN protocol (Morgan 2002). The FWIN net is a standard 61 m long monofilament gill net composed of eight 7.6 m long and 1.8 m deep panels of increasing mesh size (25, 38, 51, 64, 76, 102, 127, 152 mm stretched), which are sewn together without spacing at a hanging ratio of 55%. Netting sites were randomly selected using a 100 x 100 m grid which was superimposed over a map of the water body (scale 1:50,000). The required number of net lifts (sample size) was determined by the amount of surface area to be sampled at a desired statistical precision, specifically a mean number of walleye caught per lift at a relative standard error of less than 20%. An equal number of net locations were randomly chosen between shallow (2–5 m depth) and deep water (5–15 m), since the two depth strata cover the same amounts of surface area on Sabaskong Bay. The mesh size to be set at the shallow end of the net alternated between large and small meshes. Netting was conducted at water temperatures from 10 to 15°C in the fall of the year when walleye distribution was least likely to be affected by temperature. Nets were set in the morning and lifted approximately 24 hours later. Both surface and bottom water temperatures, along with the global positioning satellite (GPS) co-ordinates, were recorded at the terminal ends of each net at time of lift. All fish caught were identified, counted and sampled by mesh size. Total (TL) and fork lengths (FL), weight, sex and state of maturity were recorded for all species. All primary species including walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), muskellunge (*E. masquinongy*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and black crappie (*Pomoxis nigromaculatus*) were sampled for ageing tissues that included scales and at least one other calcified structure appropriate for that species (Mann 1993). Secondary species such as yellow perch (*Perca fulvescens*), cisco (*Coregonus artedii*), and common white sucker (*Catostomus commersoni*) were subsampled for ageing tissues at the rate of one out of every four fish. Mature ovaries from walleyes were collected in the field and preserved in 70% ethanol for later analysis. Fecundity was estimated gravimetrically based on egg counts of ovary subsamples (Morgan *et al.* 2003).

Data were analyzed using FISHNET 2.0 software (Lester *et al.* 1989). Relative abundance was expressed as the arithmetic mean number of fish caught per lift, pooled across all strata, and as the geometric mean catch per lift, based on the average of individual observations transformed to $\text{Log}_{10}(x + 1)$. Weight–length relationships were developed from individual round weights and total lengths that were transformed into Log_{10} values and fitted to a geometric mean predictive regression model. Condition was expressed as:

$$W = L$$

where W = round weight, L = total length, = the intercept and = slope.

Walleye maturity was assessed based on external condition of the gonads, according to criteria outlined in Duffy *et al.* (2000). Both male and female fish were considered to be mature if their gonads were in the maturing or developing

stage, where sexual products were visible but gonads had not yet achieved their full size. These same criteria were used to assess maturity of other spring spawning species in FWIN catches.

The Shannon Diversity Index (SDI; Krebs 1989), a common measure of biodiversity in ecological study, was used to evaluate the health and stability of the walleye population. This index was calculated from the number of mature females and the number of age groups containing mature females in the population. The equation for this diversity index is:

$$H = \sum_{i=1}^{K} p_i \ln p_i$$

where K is the number of different age groups with mature females, $p = n_i/N$, n_i is the number of mature females within each age group, and N is the total number of mature females in all age groups.

Growth comparisons were based on observed mean total lengths-at-age data for males and females. Prematuration growth (h) for walleye (Lester *et al.* 2000), which was defined as the growth rate up to 350 mm total length (TL) for the sexes combined, was calculated as:

$$h = 350 \text{ mm} / (T_{350} + 1)$$

where age at 350 mm (T_{350}) was interpolated from mean total lengths of two consecutive age groups whose lengths fell around 350 mm. Asymptotic length for each gender was estimated using:

$$L_\infty = L (1.0732 + 0.0223p - 0.0006p^2)$$

L = geometric mean length of the largest fish in the sample, where p (the sampling fraction expressed as a percent) = 1% of all fish in the sample (Lester *et al.* 2000).

Total length and age at 50% maturity were based upon logarithmically transformed (Log_{10}) age and length-at-maturity schedules (i.e. the percent mature at age or length) for males and females which were then fitted to a logistic regression (modified Abrosov Index; Lysack 1980). Total annual mortality (A) was calculated as:

$$A = 1 - S$$

where S is the estimator of survival (Robson and Chapman 1961, Ricker 1975) for various age groups in the observed catch.

Relative fecundity (RF) was calculated as:

RF = Number of eggs/W

where W is the wet weight of the fish in grams.

The students t-test and analysis of variance (ANOVA) were used to test for statistical significance (at = 0.05) in dif ferences between means, depending on the type of samples being compared (Steel and Torrie 1980; Statistix7 2000).

Results and Discussion

FWIN netting began on September 19, 2005 and continued until September 30 for a total of 40 sets. The relative standard error based on the mean number of walleye per net was 10.4% (40 sets) in 2005, compared to 8% (50 sets) in 2000.

Fish Community Composition

Percids (i.e. yellow perch, walleye, and sauger) were the dominant group captured in FWIN nets during the 2005 assessment, comprising 84% of the catch by number (Figure 2) and 59% of the catch by weight (Figure 3). Yellow perch were the most numerous (70.3%) and the most important species in terms of total weight (28.4%), followed by walleye (24.3%). Other important species in ranked catch weight were northern pike, muskie, white sucker, sauger and cisco.

Figure 2. Species composition of the fall walleye index net catch by number during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

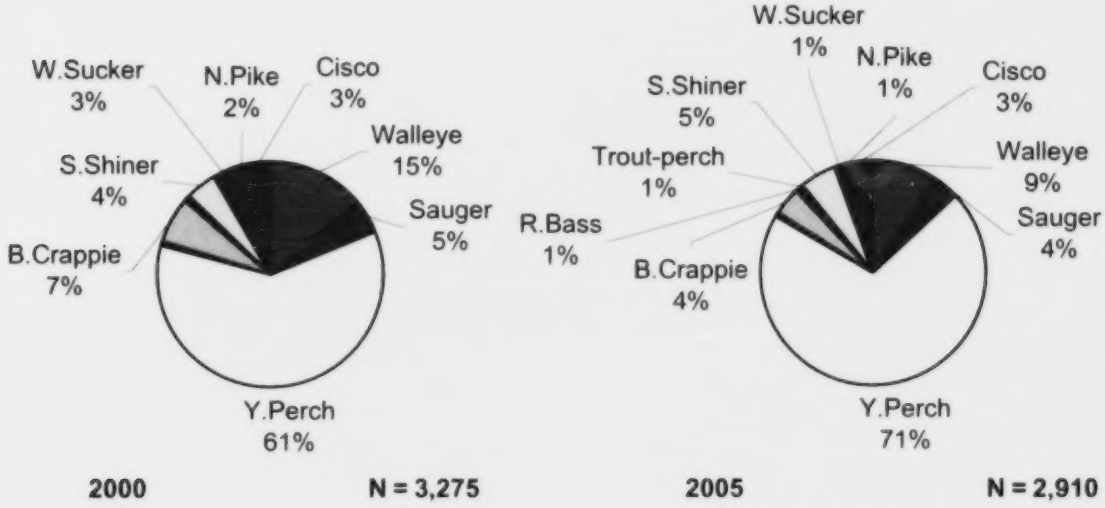
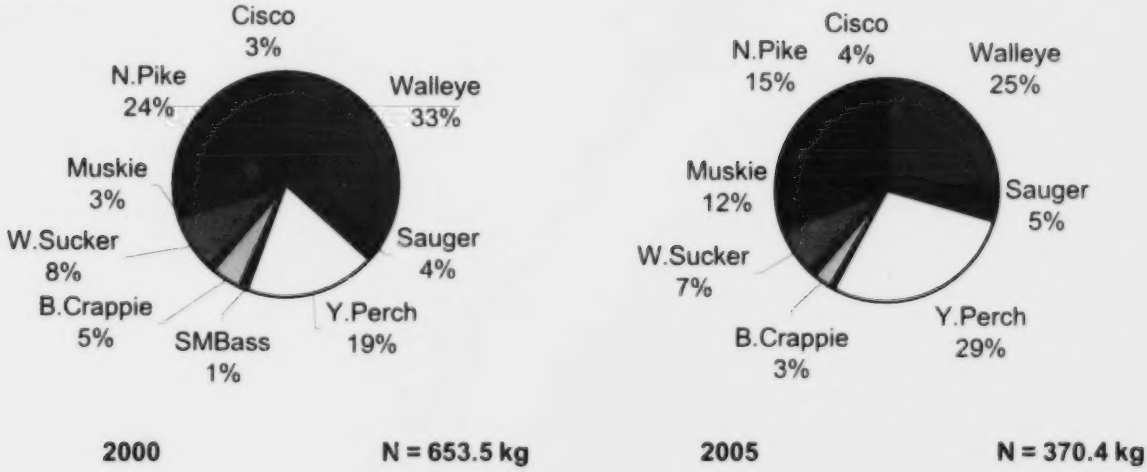


Figure 3. Species composition by weight in fall walleye index net catches during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.



It would appear that changes in the fish community of Sabaskong Bay, as illustrated by FWIN catches, have occurred between 2000 and 2005. Although mean number of fish·lift $^{-1}$ had increased only slightly from 65.6 to 72.7 ($t = -0.61$, d.f. = 88, $p = 0.5414$), mean weight had dropped significantly from 13.07 kg to 9.26 kg·lift $^{-1}$ ($t = 2.65$, d.f. = 88, $p = 0.0095$) from 2000 to 2005 (Table 1). Yellow perch accounted for the largest increase in numbers, while muskie had the largest increase in weight between years. With the exception of muskellunge, mean catch rates of larger species, especially northern pike and white suckers, declined during this period.

Table 1. Catch per unit effort expressed as the mean number (with percent relative standard error; percent RSE) and weight (kg)·net lift $^{-1}$ by species in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

Species	Mean number per lift				Mean kg per lift	
	2000	% RSE	2005	% RSE	2000	2005
Cisco	2.08	44	2.15	46	0.390	0.386
N. Pike	1.30	20	0.78	33	3.140	1.350
Muskie	0.06	57	0.23	34	0.370	1.120
W. Sucker	2.04	22	0.80	27	1.050	0.650
Spottail Shiner	2.86	29	4.00	31	0.020	0.040
B. Bullhead	0.04	100	0.03	100	0.010	0.005
Burbot	0.06	57	0.00	0	0.030	0.000
Trout-perch	0.22	37	0.38	34	0.003	0.005
R. Bass	0.26	38	0.43	38	0.040	0.030
Pumpkinseed	0.02	100	0.10	48	0.001	0.004
SMBass	0.26	44	0.13	51	0.130	0.030
LMBass	0.02	100	0.03	100	0.001	0.001
B. Crappie	4.44	20	3.00	26	0.610	0.280
Y. Perch	39.50	10	51.18	22	2.440	2.630
Sauger	3.30	26	2.80	23	0.470	0.480
Walleye	9.10	8	6.70	10	4.390	2.250
Logperch	0.00	0	0.05	100	0.000	0.001
All species	**65.60**	–	**72.70**	–	**13.070**	**9.260**
SD	**(35.73)**	–	**(72.43)**	–	**(7.33)**	**(5.79)**
Total number of lifts	**50**	–	**40**	–	**50**	**40**

Other species caught in FWIN nets included: spottail shiner (*Notropis hudsonius*), trout-perch (*Percopsis omiscomaycus*), logperch (*Percina caprodes*), brown bullhead (*Ameiurus nebulosus*), burbot (*Lota lota*), rock bass (*Ambloplites rupestris*), black crappie and pumpkinseed (*Lepomis gibbosus*). Increased abundance of trout-perch and spottail shiners, which are vulnerable to the smallest meshes in FWIN nets, were observed between 2000 and 2005. Spottail shiners, an important food of walleye, increased from about 2.9 fish·lift $^{-1}$ in 2000 to 4.0 fish·lift $^{-1}$ in 2002.

Walleye

Abundance

A significant decline in walleye abundance, both in numbers and biomass, was observed in FWIN catches from Sabaskong Bay between 2000 and 2005. The geometric mean catch for walleye decreased from 8.9 fish·lift $^{-1}$ in 2000 to 6.5 fish·lift $^{-1}$ in 2005 ($t = 2.67$, d.f. = 89, $p < 0.01$). Corresponding arithmetic mean values or catch per unit effort (CUE) were 9.1 and 6.7 fish·lift $^{-1}$ in 2000 and 2005 (Table 1). The mean catch by weight declined from 4.39 kg to 2.25

kg·lift $^{-1}$ in 2000 and 2005 ($t = 4.64$, d.f. = 87, $p < 0.01$). The geometric mean for walleye in FWIN catches for northwestern Ontario lakes was 10.7 walleye·lift $^{-1}$ during 1993–2001 (Morgan *et al.* 2003). Geometric mean catches of 4.1 walleye·lift $^{-1}$ from Shoal Lake (2001) and 12.6 walleye·lift $^{-1}$ from South Sector 5 (2002) were observed during FWIN netting.

Walleye represented 9% of the catch by number and 24% of the catch by weight from FWIN nets in 2005 (Figures 2 and 3).

Sex, Size, and Age Composition

Female walleye predominated in FWIN net catches and represented 55% and 59.5% of the sample that could be sexed in 2000 (n = 444) and 2005 (n = 247). The Shannon Diversity Index value (H), based on the number of mature female walleye by age group, was calculated at 0.75 in 2000 and 0.73 in 2005. Although values (H) greater than 0.66 indicate that the walleye population is healthy and stable (D. Pereira, Minnesota DNR, St. Paul, *pers. comm.*), the mean catch of mature females from Sabaskong Bay had declined significantly from 0.76 to 0.28 fish·lift $^{-1}$ ($t = 2.58$, d.f. = 88, $p = 0.0058$) in 2000 and 2005. The spawning stock biomass (SSB), based on the CUE for both mature males and females in catch samples, also decreased from 2.5 in 2000 to 1.2 fish·lift $^{-1}$ in 2005 while SSB values for males declined from 1.88 to 0.92 fish·lift $^{-1}$ in 2000 and 2005. A Shannon Diversity Index value for mature females of 0.88 and a spawning stock biomass CUE of 2.1 (i.e. 1.4 and 0.75 fish·lift $^{-1}$ for males and females) were observed during a FWIN of South Sector 5 in 2002 (Mosindy and Mucha 2006).

A shift to slightly smaller and younger walleye was observed when 2000 and 2005 FWIN catches were compared (Figures 4 and 5). Most fish were 200–400 mm TL in both years, representing about 78% and 67% of the catch in 2000 and 2005. The mean catch of "quality-sized" walleye (>380 mm TL) declined significantly from 2.2 fish·lift $^{-1}$ in 2000 to 1.1 fish·lift $^{-1}$ in 2005 ($t = 3.32$, d.f. = 88, $p < 0.001$). The mean total length of walleye in FWIN nets decreased from about 339 mm in 2000 to 297 mm in 2005. This most likely reflects the increased removal of larger fish from the population.

Walleye caught in FWIN nets were predominantly 0 to 4 years old (Figure 5). Fish older than 4 years were poorly represented in both sampling years, dropping from about 13% in 2000 to less than 5% of the observed catch in 2005. The number of contributing age groups also declined from 14 in 2000 to 12 in 2005. All age groups from 0 to 11 were present in the 2005 catch. The 2003 year class, comprised of two year olds, was the largest single age group, followed by four year olds of the 2001 year-class.

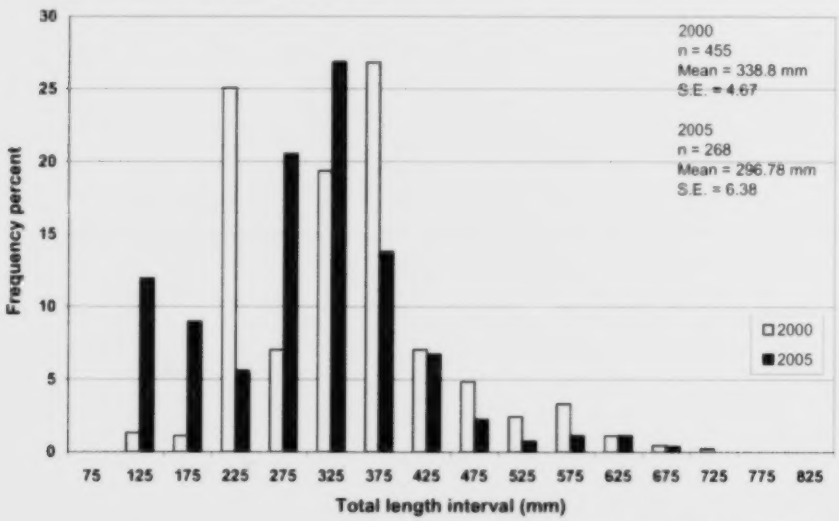


Figure 4. Total length frequency (mm) comparison of walleye caught in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

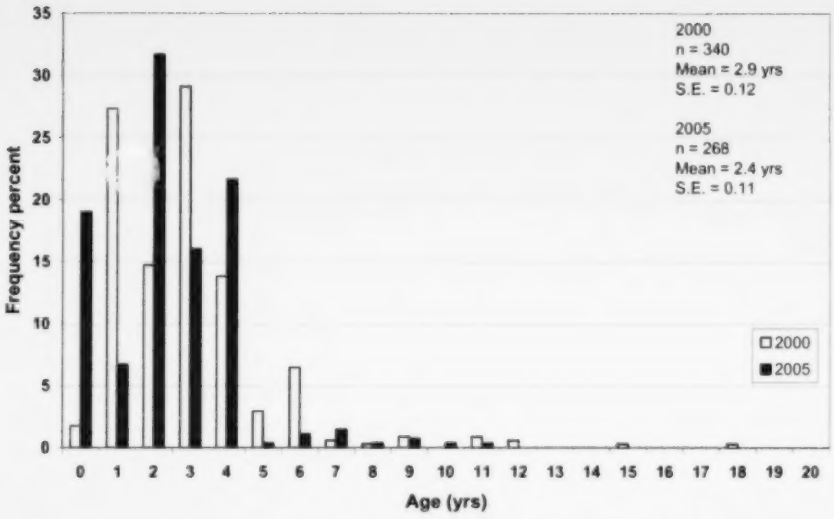


Figure 5. Age frequency comparison of walleye caught in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

Weight–Length Relationship

The weight–length relationships were calculated as:

$W = (1.98e - 006)(L^{3.20})$ for walleye (sexes combined) in 2000;
$W = (3.25e - 006)(L^{3.17})$ for walleye (sexes combined) in 2005.

A comparison of these relationships indicated a slight decline in overall condition for walleye in Sabaskong Bay between sampling years. Weights-at-length for Sabaskong Bay walleye were about average for both males and females when compared to Northwest Region lakes (Morgan *et al.* 2003).

Growth

Mean total lengths-at-age were similar in 2000 and 2005 catches (Figure 6). Mean total length-at-age values for both males and females (Table 2) were about average for northwest Ontario populations when compared with regional walleye growth benchmarks reported in Morgan *et al.* (2003). Asymptotic lengths (L infinity) for female walleye decreased from 740 mm in 2000 to 719 mm in 2005, while L infinity values for males decreased from 628 mm to 618

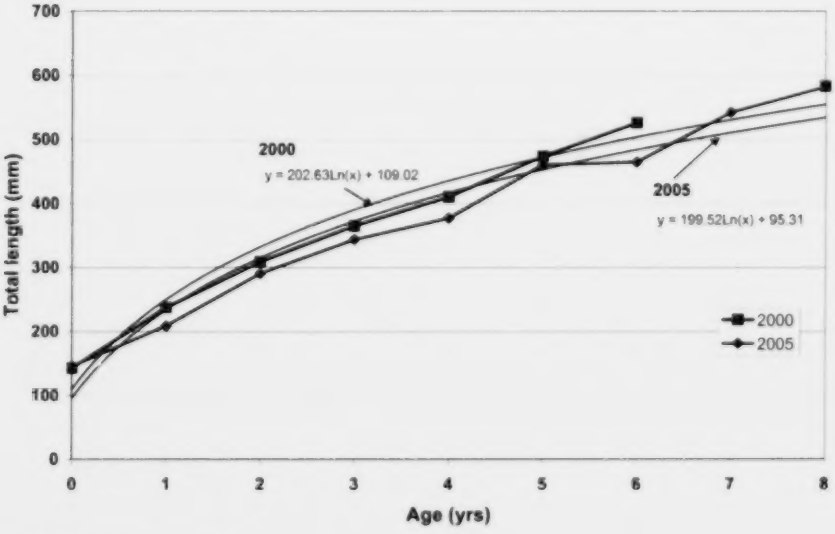


Figure 6. Mean total length-at-age comparison for walleye (sexes combined) caught in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

mm during the same period. Prematuration growth (h) for walleye during their early growth period (ages 0–3) declined slightly from 81.7 mm·yr $^{-1}$ in 2000 to 76.9 mm·yr $^{-1}$ in 2005.

Table 2. A comparison of mean total lengths-at-age (mm) for male, female and all walleye caught in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont. Sample sizes appear in brackets.

Age	Mean total length (mm)					
	Males		Females		Sexes combined	
	2000	2005	2000	2005	2000	2005
0	–	150	158	153	142	146
	–	(14)	(2)	(16)	(6)	(51)
1	237	209	238	208	237	208
	(37)	(7)	(50)	(11)	(93)	(18)
2	310	291	308	290	309	290
	(24)	(30)	(26)	(55)	(50)	(85)
3	362	326	367	354	365	343
	(48)	(17)	(51)	(26)	(99)	(43)
4	401	370	418	384	410	377
	(21)	(29)	(26)	(29)	(47)	(58)
5	417	–	488	460	474	460
	(2)	–	(8)	(2)	(10)	(2)
6	488	413	558	516	526	464
	(10)	(2)	(12)	(2)	(22)	(4)
7	–	–	–	561	–	542
	–	–	–	(2)	–	(4)
8	–	–	583	582	583	582
	–	–	(2)	(2)	(3)	(2)

Sauger

Abundance

The sauger catch did not change, with geometric mean catches of 2.45 and 2.5 fish·lift $^{-1}$ in 2000 and 2005. The representation of sauger in FWIN nets was about 4 to 5% of the catch by number and weight in 2000 and 2005 (Figures 2 and 3). The sauger catch averaged 0.47 kg and 0.48 kg·net lift $^{-1}$ in 2000 and 2005 (Table 1).

Size and Age Composition

A slight shift to larger and older sauger was observed when 2000 and 2005 FWIN catches were compared. The mean size of sauger caught in FWIN nets increased from 251 mm TL and 140.8 g in 2000 to 274 mm TL and 169.7 g in 2005. Similarly, the percentage of sauger ≥ 250 mm increased from 53% in 2000 to 70% in 2005. The mean age of sauger increased from 2.3 years of age in 2000 to 2.8 years of age in 2005. Eight age groups were present in 2000 (age 0–7) compared with six (age 0–6; age 1 missing) in 2005. Saugers older than age 7 were absent during both sampling years.

Growth

Growth rates of sauger, expressed as mean total length-at-age (Table 3), were similar between 2000 and 2005 FWIN samples. Growth rates were also similar to those observed in nearby South Sector 5 during 2002 (Mosindy and Mucha 2006).

Age	Mean total length (mm)						
	Males		Females		Combined		
	2000	2005	2000	2005	2000	2005	South 5 2002
0	–	137	131	–	128	137	132
	–	(1)	(1)	–	(3)	(1)	(2)
1	187	–	181.9	–	184	–	188
	(22)	–	(21)	–	(44)	–	(168)
2	239	247	243	247	240	247	243
	(11)	(21)	(33)	(31)	(45)	(53)	(136)
3	283	273	301	292	297	283	279
	(12)	(16)	(48)	(18)	(61)	(34)	(308)
4	319	254	319	322	319	317	308
	(2)	(1)	(4)	(14)	(6)	(15)	(157)
5	–	314	352	–	352	314	333
	–	(4)	(2)	–	(2)	(4)	(93)
6	342	340	–	366	342	356	342
	(3)	(2)	–	(3)	(3)	(5)	(14)
7	365	–	–	–	365	–	370
	(1)	–	–	–	(1)	–	(9)
8	–	–	–	–	–	–	391
	–	–	–	–	–	–	(9)

Table 3. A comparison of mean total lengths-at-age (mm) for sauger caught in fall walleye index gill nets during 2000 and 2005, from Sabaskong Bay and during 2002 from South Sector 5, Lake of the Woods, Ont. Sample sizes appear in brackets.

Maturity

Although differences in maturity schedules for sauger were evident between sexes, ages at onset of maturity changed little between assessment years. Estimated age at 50% maturity increased from 3.2 years to 3.4 years for females but decreased from 2.3 years to 2.1 years for males from 2000 to 2005. All males ≥ age 4 and all females ≥ age 5 were maturing and considered to be mature when examined in 2005. Sauger in Sabaskong Bay appeared to mature earlier than those sampled from nearby South Sector 5 where 100% maturity was not achieved until age 5 for males and age 6 for females in 2002 (Mosindy and Mucha 2006).

Mortality

Since sauger appeared to be fully recruited to FWIN gillnets at age 3 years, total annual mortality (A) rates were calculated for fish ≥ 4 years of age. Estimated total annual mortality rates for the sexes combined were 50% in 2000 and 62% in 2005. Estimated total annual mortality rates increased from 36% to 43% for males, and from 71% to 73% for females during this same period. Total annual mortality rates of 62% for males, 56% for females and 58.5% for the sexes combined were observed in FWIN catches from South Sector 5 in 2002.

Northern Pike

A limited number of northern pike were captured in 2000 and 2005, since FWIN nets are not as effective in capturing pike as other species (Morgan 2002). However, abundance and age/size characteristics of this species were compared between years, since pike are a species of concern in Sabaskong Bay.

A significant decline in northern pike abundance, both in numbers and biomass, was observed in fall walleye index nets from 2000 and 2005. The geometric mean number of pike·lift $^{-1}$ declined from 1.8 in 2000 to 1.4 in 2005

($t = 3.85$, d.f. =88, $p < 0.01$). Relative abundance values were higher than those observed during FWIN netting in nearby South Sector 5 (i.e. 0.6 pike·lift^{-1}; Mosindy and Mucha 2005). Northern pike represented 1% of the overall catch by number but 15% of the catch by weight in the 2005 Sabaskong FWIN (Figures 2 and 3). The mean catch by weight dropped from 3.14 to 1.35 kg·lift^{-1} during 2000 to 2005 ($t = 4.19$, d.f. = 88, $p < 0.01$). Northern pike averaged 2.76 kg per lift during 2002 in South Sector 5.

Both mean size and age of northern pike declined in catch samples from FWIN nets during 2000 and 2005. The mean size of northern pike dropped from 701 mm and 2,414 g in 2000 to 621 mm and 1,740 g in 2005. Mean age declined from 4.6 years in 2000 to 3.8 years in 2005. A strong representation of age 2 fish of the 2003 year-class could account for observed declines in both mean age and size during 2005. Eight age classes (1–9 years) were present in the 2000 FWIN while nine different age classes (0–11 years) were observed in 2005. However, the mean catch of fish ≥ 700 mm TL declined from 0.64 to 0.18 fish·lift^{-1} during 2000 to 2005, even though daily catch/possession limits were reduced from six to four fish per day and a protected 700–900 mm slot size regulation, allowing one over 900 mm, were adopted in 1999. These regulation changes had the objective of increasing numbers of larger pike in the fishery (Ontario Ministry of Natural Resources 2004).

All male pike were observed as mature and maturing at ages 2 or older in 2000 and 2005 FWIN samples. All females were not mature until age 4 in 2000 and age 2 in 2005. Ages at maturity were similar to those observed for pike in FWIN catches from South Sector 5 in 2002.

Estimated total annual mortality (A) for the sexes combined, calculated for age 3 years and older, had declined from 34% in 2000 to 25% in 2005.

Yellow Perch

Abundance and Age/Size Characteristics

Yellow perch abundance increased slightly between years, based on a geometric mean catch of 31.3 and 32.5 fish·lift^{-1} in 2000 and 2005, although arithmetic means increased from 39.5 (n = 1975, S.E. = 4.05) to 51.2 (n = 2047, S.E. = 11.34) during the same period (Table 1). A difference between geometric and arithmetic mean values can be attributed to the fact that yellow perch catches were not evenly distributed between lifts. Yellow perch comprised about 60% and 70% of the total catch by number in 2000 and 2005, while their representation in the overall catch biomass increased from about 19% in 2000 to 29% in 2005. The average size of yellow perch declined from 162 mm and 61.7 g (n = 1975) in 2000 to 149 mm and 49.5 g (n = 1987) in 2005. Yellow perch ≥ 100 g comprised 20% of the catch in 2000 and 11.6% in 2005, as compared to 23% in nearby South Sector 5 in 2002 (Mosindy and Mucha 2006). The mean age of yellow perch in the catch decreased slightly from 3.2 years (n = 471, S.E. = 0.08) in 2000 to 3.0 years (n = 463, S.E. = 0.07) in 2005. Eight age classes were caught in 2005, as compared with 11 age classes in 2000 (Figure 7). A strong 2003 year-class, representing two year olds, comprised 37.6% of the 2005 catch sample.

Growth

Growth rates of both male and female yellow perch in Sabaskong Bay, based on a comparison of mean total lengths-at-age, decreased slightly between 2000 and 2005 sampling (Table 4). Females were larger than males at all ages in both years. Yellow perch in Sabaskong Bay appeared to grow more slowly than perch in nearby South Sector 5 (Mosindy and Mucha 2006).

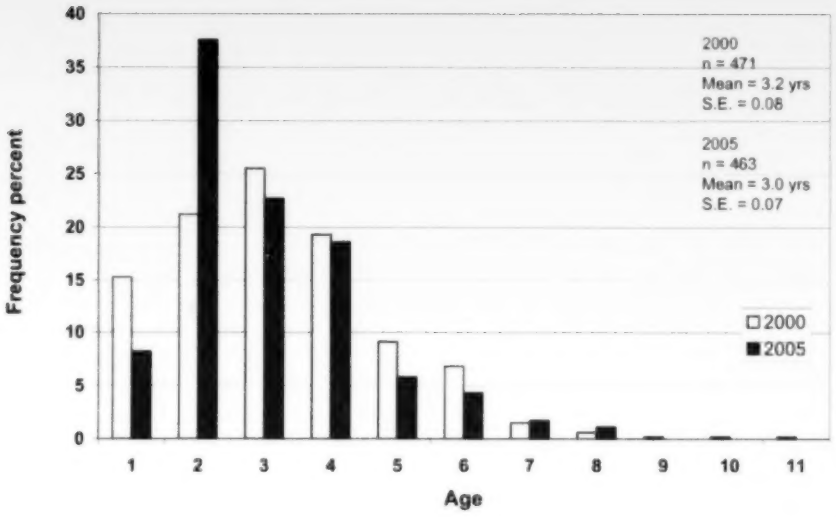


Figure 7. Age frequency comparison for yellow perch caught in fall walleye index gill nets during September, 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

Maturity

Maturity rates for both male and female yellow perch remained unchanged between 2000 and 2005 FWINs. Some males were maturing at age 2 and all had reached full maturity by age 3. Most females were maturing by the end of their fourth summer and were fully mature at age 7 or 250 mm TL. Ages at 50% maturity (modified Abrosov Index) were 1.1 years for males and 3.3 and 3.5 years for females in 2000 and 2005, respectively.

Table 4. A comparison of mean total lengths-at-age (mm) for both sexes of yellow perch caught in fall walleye index gill nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont. Sample sizes appear in brackets.

Age	Mean total length (mm)					
	Males		Females		Sexes combined	
	2000	2005	2000	2005	2000	2005
1	103	100	107	101	104	101
	(47)	(24)	(21)	(14)	(68)	(38)
2	133	126	147	147	139	134
	(57)	(106)	(42)	(68)	(99)	(174)
3	162	151	178	173	170	163
	(57)	(47)	(63)	(58)	(120)	(105)
4	185	175	204	203	199	196
	(25)	(21)	(66)	(65)	(91)	(86)
5	197	173	233	213	228	204
	(6)	(6)	(37)	(21)	(43)	(27)
6	201	217	246	236	243	235
	(2)	(2)	(30)	(19)	(32)	(21)
7	231	226	263	264	258	259
	(2)	(2)	(6)	(7)	(8)	(9)
8	–	–	–	278	–	278
	–	–	–	(5)	–	(5)

Mortality

The estimated total annual mortality (A) rate for yellow perch ≥ age 3 from Sabaskong Bay increased slightly from 47% in 2000 to 49.3% in 2005. Mortality for males and females increased slightly from 63.6% to 65% and 42% to 44.5% between 2000 and 2005. Mortality rates were similar to those

observed for perch from nearby South Sector 5 (i.e. 46%) during a 2002 FWIN.

Black Crappie

Black crappies were poorly represented in fall walleye index gill nets, probably owing to size selectivity of the gear. FWIN catches from 2000 and 2005 were compared since they provided important samples of smaller and younger fish than are normally observed in other assessment programs.

Based on FWIN catches, the relative abundance of black crappie decreased from an average of 4.4 to 3 fish·lift $^{-1}$ and 0.61 to 0.28 kg·lift $^{-1}$ between 2000 and 2005 (Table 1). Black crappie represented about 3% of the total catch by weight in 2005 (Figure 3). The mean age and size of crappies in the catch dropped from 2.4 years (n = 80, SE = 0.19), 193 mm TL and 137.8 g (n = 222) in 2000 to 1.75 years (n = 116, SE = 0.1), 165 mm TL and 90.1 g (n = 116) in 2005. All age groups from 0–7 years and 0–5 years were represented during 2000 and 2005. Two-year-olds were the dominant age group in both years and comprised 39% and 58% of catch samples in 2000 and 2005. The representation of fish ≥ age 4 and 250 mm TL declined from about 20% of the sample in 2000 to less than 3.5% in 2005.

Growth, expressed as mean total length at age, was comparable between survey years (Figure 8). Black crappies averaged 83 mm (n = 8, range = 68–113 mm) and 73 mm (n = 27, range = 64–82 mm) in length by the end of September during their first summer in 2000 and 2005. Over 80% of crappies could be sexed in both years, resulting in male to female ratios of 0.96 and 0.94 in 2000 and 2005. The mean age at maturity decreased from 1.6 to 1.0 year for males but increased from 1.9 to 2.6 years for females when 2000 and 2005 FWIN samples were compared. All males were maturing and considered to be mature at age one while all females were mature at age 3 in 2005. Estimated total annual mortality (A) for crappies ≥ age 3 increased from 41% to 80% from 2000 and 2005.

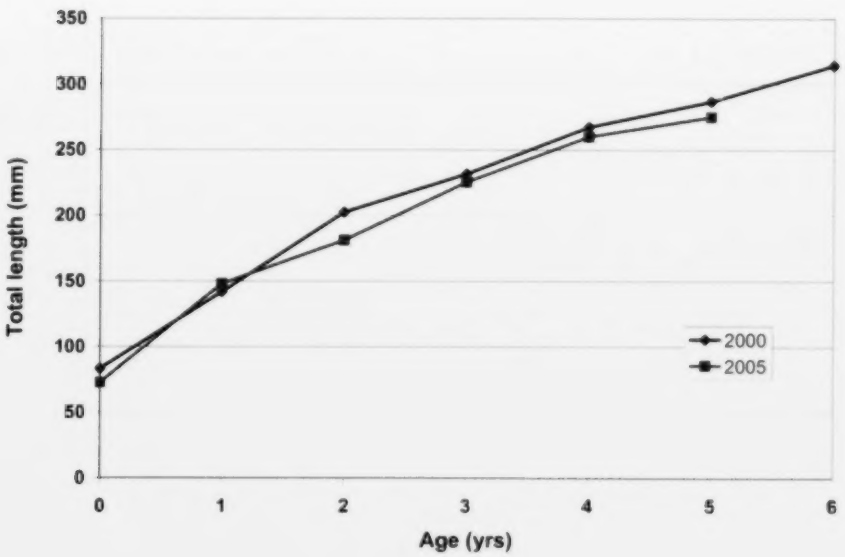


Figure 8. Mean total length at age comparison for black crappie (sexes combined) caught in FWIN nets during 2000 and 2005, Sabaskong Bay, Lake of the Woods, Ont.

Cisco

Cisco abundance in Sabaskong Bay appeared to be stable, based on an average FWIN catch of 2.2 fish·lift $^{-1}$ and 0.39 kg·lift $^{-1}$ during 2000 and 2005 surveys (Table 1). Cisco formed a minor component of the fish community when compared to nearby South Sector 5 where they averaged 13.3 fish·lift $^{-1}$ and 4.26 kg·lift $^{-1}$ in FWIN nets during 2002. The average size and age of cisco in Sabaskong Bay decreased slightly from 243 mm TL, 187.9 g (n = 104) and 2.2 years (n=30) in 2000 to 242 mm, 179.3 g (n = 86) and 2 years (n = 38) in 2005. Cisco caught in FWIN nets ranged in age from 1–7 years in 2000 and 0–6 years in 2005 with no missing age classes.

Cisco growth rates in Sabaskong Bay, expressed as mean total lengths at age for both male and females (Table 5), were similar to those observed in the 2000 FWIN and in nearby South Sector 5 (Mosindy and Mucha 2006). All males at age 2 and all females at age 4 were fully developed and mature in FWIN samples from Sabaskong Bay. Estimated total annual mortality (A) rates for ages 3 and older, were 36.4% in 2000 and 28.6% in 2005, as compared to 46.8% in Sector 5.

Age	Mean total length (mm)		
	2000	2005	South Sector 5
1	216	175	214
	(18)	(10)	(33)
2	262	265	274
	(3)	(21)	(35)
3	301	330	302
	(4)	(2)	(148)
4	340	333	335
	(14)	(4)	(27)
5	–	338	338
	–	(2)	(52)
6	–	–	345
	–	–	(6)
7	352	–	360
	(4)	–	(6)
8	–	–	348
	–	–	(9)
9	–	–	365
	–	–	(9)

Table 5. A comparison of mean total length-at-age for cisco caught in fall walleye index gill nets during 2000 and 2005 from Sabaskong Bay, and during 2002 from South Sector 5, Lake of the Woods, Ont. Sample sizes appear in brackets.

Conclusions

Results from fall walleye index netting in Sabaskong Bay indicated an increase in the number of smaller fish, especially yellow perch, trout-perch and spot-tail shiners but a decline in both numbers and/or weight of larger species between 2000 and 2005 sampling years.

The overall status of the walleye population in Sabaskong Bay had deteriorated since the last FWIN assessment in 2000. Walleye abundance in FWIN nets dropped significantly from a geometric mean catch of 8.9 fish·lift $^{-1}$ in 2000 to 6.5 fish·lift $^{-1}$ in 2005. This was still above a mean catch of 4.1 walleyes·lift $^{-1}$ from Shoal Lake (Gillies 2003) but well below 12.6 walleyes·lift $^{-1}$ from nearby South Sector 5 in 2002 (Mosindy and Mucha 2006) and the Northwest Region average of 10.7·lift $^{-1}$ (Morgan *et al.* 2003).

A shift to slightly younger and smaller walleyes was accompanied by declines in the proportion of "quality-sized" fish, in the percentage of fish older than age 4, and in the number of contributing age groups when FWIN catches from 2000 and 2005 were compared. Although a Shannon Diversity Index value of 0.73 indicated a healthy diversity of age classes amongst mature females, the spawning stock biomass (SSB), based on mean catches of both mature male and female walleyes, had decreased by over 50% from 2.5 to 1.2 fish·lift $^{-1}$. Growth, condition and maturity rates were similar to those observed during the 2000 FWIN. Estimated total annual mortality (A) rates for fish, age 5 and older, were average for walleye in the northwest region, although total mortality for fish, age 3 and older, remained high and approached 50%. Fewer than two fish in 10 will survive an additional two years when annual mortality rates exceed 50%. The long-term sustainability of a stock is placed at increasing risk when age groups not yet fully mature are exposed to such high mortalities. This already appears to be the case in Sabaskong Bay where walleye age distributions are limited to fish age 4 and younger. A significant increase in fecundity from 56.3 to 76.6 eggs·g $^{-1}$ between 2000 and 2005 is indicative of a compensatory response to increased exploitation stress but it can also reflect changes in food, energy availability, population density, population structure and behaviour (Baccante and Reid 1988).

Observed declines in angling success rates and yields for walleye in Sabaskong Bay during 2005 (Spendlow 2006) when compared to previous surveys were supported by our FWIN results. These declines have occurred despite the increased frequency of strong year class production in recent years that has resulted in improved angling success rates and yields in most other sectors of the lake (Mosindy 2003, Spendlow 2006). This also followed reductions in daily catch/possession limits. The Canadian resident daily catch/possession limit for walleye and sauger (or any combination) was reduced in 1999 from six to four, only two with a Conservation Licence, with only one greater than 46 cm in total length. Catch limits for non-residents of Canada, fishing in the Ontario–Minnesota border waters area, were reduced from six walleye/saugers to two fish, with four in possession, only one greater than 46 cm long in year 2000.

Changes in population characteristics of other species caught in FWIN gear were also indicative of increased exploitation stress during 2000–2005. Although changes in abundance were not significant for most species, with the exception of northern pike and white suckers, declines in size and age class structure were evident. Total annual mortality rates for sauger, yellow perch and black crappie had increased while the number of contributing age groups and the representation of larger "quality-sized" fish in catch samples had declined. The abundance of pike larger than 700 mm in length had also decreased even though daily catch/possession limits were reduced from six to four fish per day and a protected 700–900 mm slot size regulation, with only one over 900 mm, were adopted in 1999, with the objective of increasing the numbers of larger pike in the fishery (Ontario Ministry of Natural Resources 2004). Improvements in the abundance and size structure of northern pike populations in nearby South Sector 5 (Mosindy and Mucha 2006) and other parts of Lake of the Woods have been observed in recent years. Although overall numbers remained low, an increase in the mean catch of muskellunge in FWIN nets from Sabaskong Bay during the 2000–2005 period reflects an increasing trend in muskie abundance in other Ontario sectors of the lake, following changes to minimum size regulations and harvest rates after 1987 (Mosindy and Duffy 2007). Both northern pike and muskellunge are large terminal predators and may compete for similar types and sizes of prey. Unlike northern pike which are exposed to high harvest pressure by both angling and commercial fisheries under current regulations, muskellunge with a 137 cm (54 in.) minimum size limit on Lake of the Woods are managed largely as a catch and release sport species.

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Appendix A

Table A1. Relative fecundity (number of eggs per gram total fish weight) of walleye sampled from fall walleye index gill nets during 2000, Sabaskong Bay, Lake of the Woods, Ont.

Year	Sample	TLEN (mm)	Age	FISHWT (g)	GONWT (g)	Estimated FECUN	Eggs/g (FISHWT)
2000	6-49-1	564	6	1844	45.27	116389	63.12
	6-49-2	436	4	812	15.26	42967	52.92
	6-49-3	479	4	1000	16.91	54467	54.47
	7-23-1	584	6	1916	31.70	101376	52.91
	8-12-1	715	11	4150	93.59	228890	55.15
	8-12-5	608	6	2250	46.51	125360	55.72
	9-4-1	552	6	1700	29.05	71628	42.13
	9-4-3	577	6	1850	27.37	84245	45.54
	13-16-4	458	4	1044	25.02	57179	54.77
	14-20-1	460	6	894	18.45	45608	51.02
	14-20-2	548	6	1398	32.02	86091	61.58
	14-20-8	422	4	716	12.21	41347	57.75
	15-42-1	556	5	1870	30.40	80053	42.81
	15-42-2	527	6	1502	36.65	89597	59.65
	17-1-1	550	5	1850	43.79	106118	57.36
	17-1-3	454	3	960	17.67	50401	52.50
	17-1-4	498	5	1278	32.95	78531	61.45
	19-28-7	614	6	2758	90.07	191669	69.50
	22-33-1	594	6	2800	70.73	142238	50.80
	34-5-1	553	6	1690	49.79	91282	54.01
	35-50-1	650	6	3300	83.68	141474	42.87
	39-30-2	646	11	3010	97.12	182812	60.74
	40-46-14	463	4	972	24.57	54955	56.54
	41-22-16	583	8	2100	77.70	141129	67.20
	42-41-2	448	4	840	19.70	57071	67.94
	45-18-1	591	9	2400	97.36	135428	56.43
	45-18-2	667	12	3700	144.15	199648	53.96
	45-18-3	638	9	3150	113.94	157807	50.10
	45-18-5	491	5	1186	56.31	91166	76.87
	48-11-1	639	9	3000	108.71	211767	70.59
	50-6-10	475	5	1096	18.61	52275	47.70
	Average	**548.30**	**6.20**	**1904.40**	**51.80**	**106805.40**	**56.30**
	SD	**78.53**	**2.26**	**935.96**	**35.64**	**54202.96**	**8.36**

Appendix B

Table B1. Relative fecundity (number of eggs per gram total fish weight) of walleye sampled from fall walleye index gill nets during 2005, Sabaskong Bay, Lake of the Woods, Ont.

Year	Sample	TLEN (mm)	Age	FISHWT (g)	GONWT (g)	Estimated FECUN	Eggs/g (FISHWT)
2005	4-44-1	575	7	2072	59.36	179267	87
	7-47-1	457	4	956	18.19	70601	74
	10-43-1	524	7	1464	27.24	105246	72
	28-13-2	495	4	1314	33.24	100496	76
	34-42-1	613	9	2722	83.04	206493	76
	36-21-4	698	11	4014	186.64	319590	80
	35-21-5	633	10	2974	149.55	295959	100
	39-11-1	625	9	2492	72.10	152852	61
	39-11-2	584	7	1920	40.44	116144	60
	40-14-5	582	8	2170	62.82	193360	89
	3-5-4	338	4	354	5.31	24231	68
	Average	**556.70**	**7.30**	**2041.10**	**67.10**	**160385.40**	**76.60**
	SD	**98.99**	**2.45**	**1017.22**	**55.77**	**90849.58**	**12.01**

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